MUSCULO-SPIRAL (RADIAL) PARALYSIS DUE TO DISLOCATIONS OF THE HEAD OF THE RADIUS.

WITH ESPECIAL REFERENCE TO THOSE CASES COMPLICATING FRACTURE OF NEW YORK,

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THE question of injury to the musculo-spiral nerve, perhaps the most frequently affected nerve in the body, has been treated exhaustively in the medical literature, but that particular form due to dislocations of the radial head has been surprisingly neglected. The scant respect shown this important combined lesion which represents a distinct pathological and clinical entity, its comparative frequency and practical significance, and the possibility of a completely successful surgical treatment of the condition have induced the writer to report, in detail, the following case which first came under his observation while he was house-surgeon at the German Hospital, New York. In connection with this report, he has reviewed the literature of the subject, laying particular stress upon those cases complicating fracture of the ulna, and finally, he has made a number of cadaver experiments to determine the anatomical relations of the dislocated radial head to the musculo-spiral nerve.

Patient F. P., printer, aged 19. On August 12, 1903, while the patient was winding a cable of a theatre curtain, the crank slipped from his hand, reversed, and forcibly struck his right forearm. He was unable to use his arm, and a doctor made the diagnosis of fracture of the ulna. The patient states that shortly after the injury he noticed that he could not extend his wrist or fingers, and that the back of the hand and half of the fingers felt numb. The arm was put in a splint, which was worn for four weeks, and when this was removed there was decided impairment of the function of the elbow, while the condition of the wrist, hand, and fingers was unchanged. These functional disturbances persisted until the patient's admission to the German Hospital, New York, on November 13, 1903, three months after the injury.

EXAMINATION.—*Inspection* of the right forearm shows a depression on the ulnar side at the junction of the upper and middle third and a marked prominence on the radial side of the cubital fossa. There is a drop-wrist. The forearm is atrophied and the skin of the dorsum of the hand looks bluish and glossy.

Palpation reveals a distinct deformity of the ulna corresponding to the depression and caused by a bowing of the bone, forwards and radially. The fragments are firmly united; there is considerable callus at the point of fracture; the angle formed by the two fragments is about 160 degrees; the upper fragment is displaced inward and backward, the lower outward and forward. The prominence in the bend of the elbow is the radial head, resting on the lateral condyle of the humerus. It is slightly thickened. It rotates in pronation and supination. The dorsum of the hand is cold.

Active Motion. At the Elbow.—Flexion is limited to about 100 degrees. Extension is unaffected. Pronation and supination are somewhat restricted, particularly the latter.

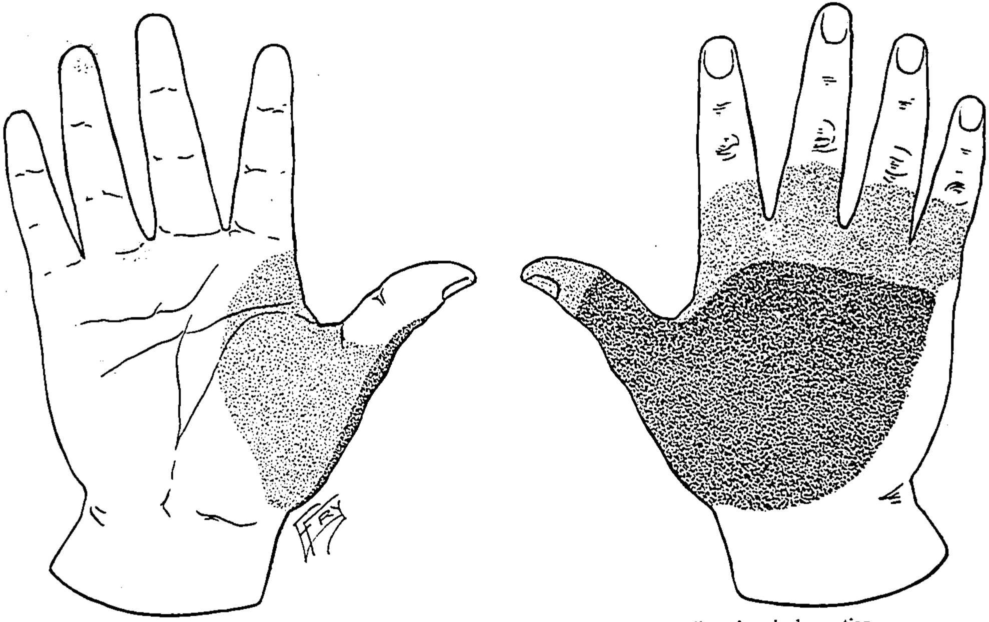
At the Wrist.—Flexion is normal. Extension is only possible for about 15 degrees from the drop-wrist position. Abduction is slightly limited. Adduction is not impaired.

At the Fingers.—Flexion is normal. The proximal phalanges and the thumb cannot be, while the two distal phalanges of the four fingers can be extended. The abduction and adduction of the four fingers are normal, but the thumb cannot be abducted.

Passive Motion.—Flexion, pronation, and supination at the elbow are limited to the same extent as the corresponding active motions. Forcing produces considerable pain. Extension of the elbow and all the movements of the wrist and fingers are passively uninterfered with. The patient's grip is weak, but is somewhat strengthened on passive extension of the wrist.

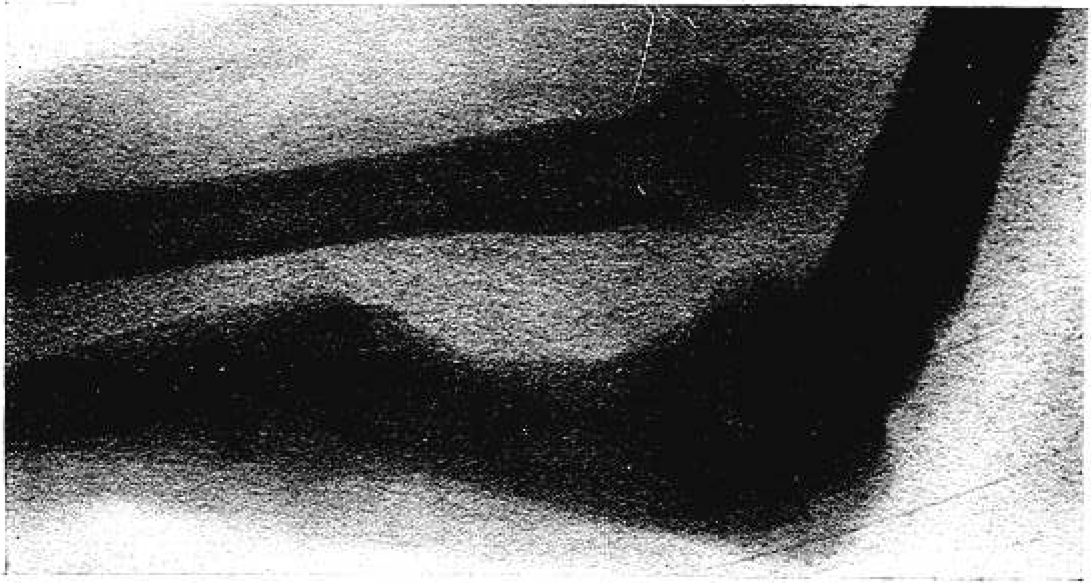
Sensation.—There is practically a total loss of sensation of the entire dorsum of the hand which extends to the phalangeal joint of the thumb and almost to the metacarpo-phalangeal articulations of the fingers. This area of anaesthesia reaches nearly to

FIG. 1.



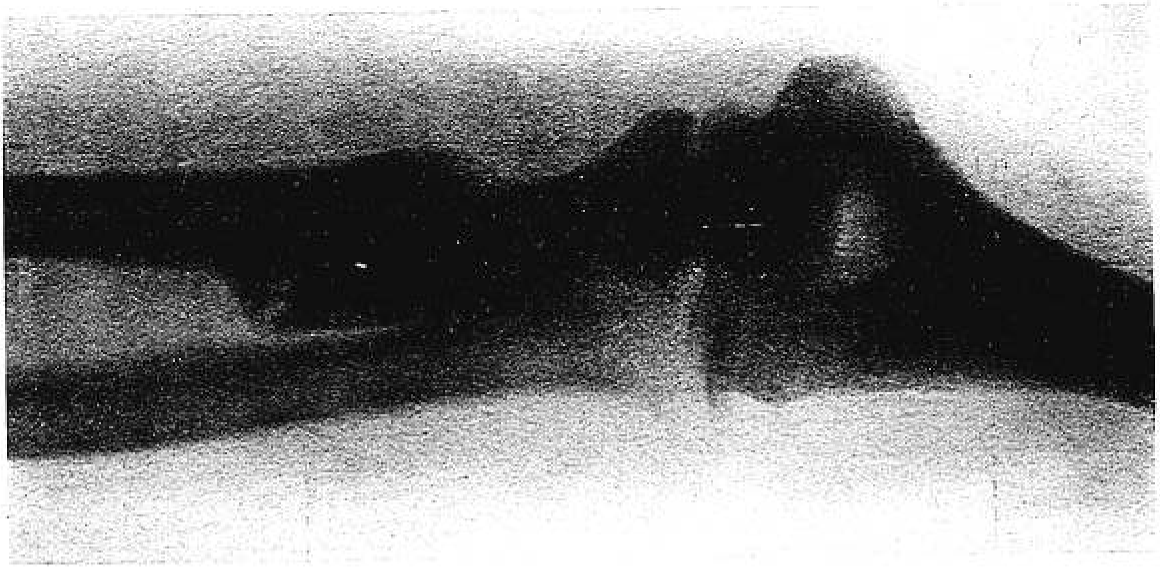
Areas of anæsthesia. Dark shading—practically total anæsthesia. Light shading—impaired sensation.

FIG. 2



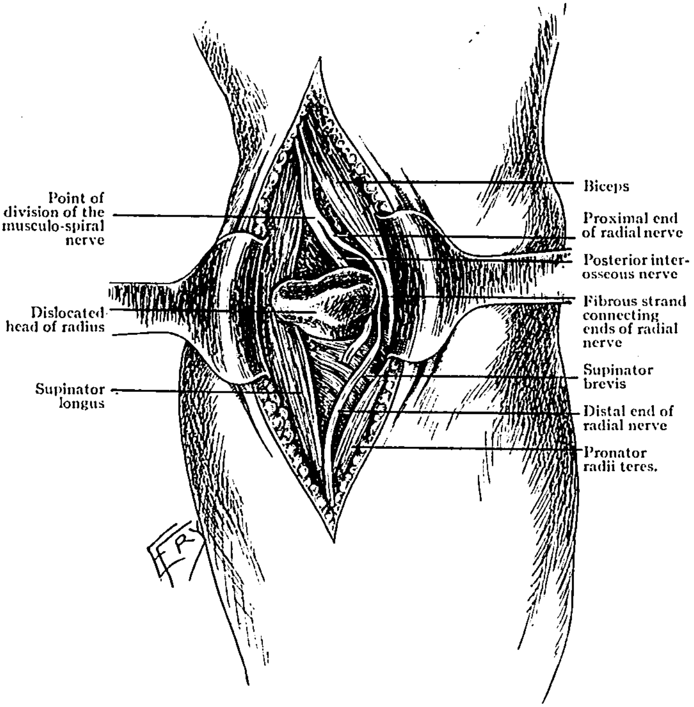
Skiagram before operation. Flexion. Lateral.

Fig 3.



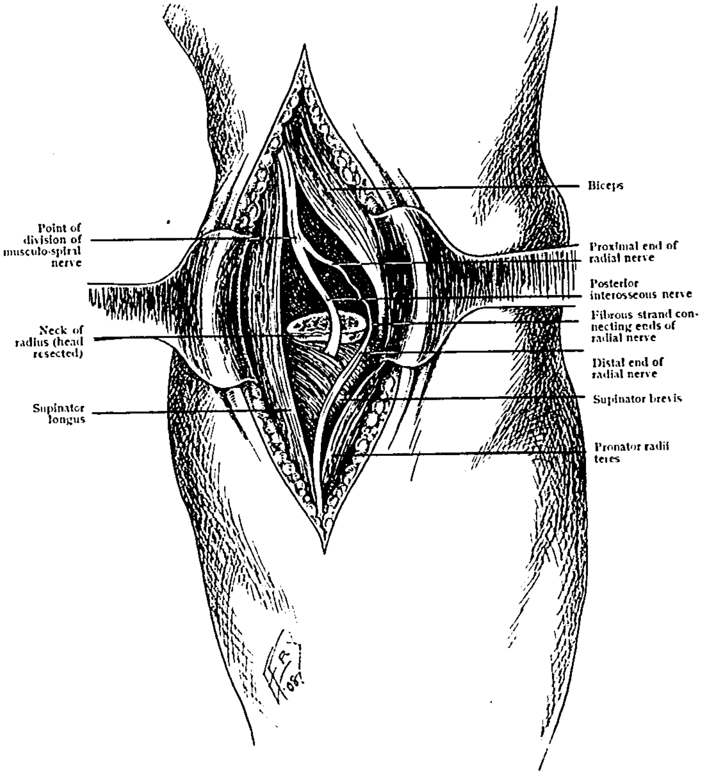
Skiagram before operation. Extension. Anteroposterior.

FIG. 4.


Point of division of the musculo-spiral nerve
Dislocated head of radius
Supinator longus
Biceps
Proximal end of radial nerve
Posterior interosseous nerve
Fibrous strand connecting ends of radial nerve
Supinator brevis
Distal end of radial nerve
Pronator radii teres.
F R

Condition at operation.

FIG. 5


Biceps
Point of division of musculo-spiral nerve
Proximal end of radial nerve
Posterior interosseous nerve
Fibrous strand connecting ends of radial nerve
Neck of radius (head resected)
Distal end of radial nerve
Supinator brevis
Supinator longus
Pronator radii teres

Appearance after resection of head of radius.

the wrist. On the ulnar side of the back of the hand there is a narrow strip of normal sensation. The dorsal surfaces of the distal phalanx of the thumb and the proximal phalanges of the fingers show impaired sensation, as does the thenar eminence. (See Fig. 1.)

Electrical Reactions.—There is a total loss of faradic contractility of the extensor communis on direct stimulation. This muscle is more excitable to galvanism, and A. C. C.>K. C. C. On stimulating the musculo-spiral nerve in the arm, the extensor communis reacts neither to faradism nor galvanism, but the extensor carpi radialis longior and the supinator longus react normally.

Mensuration shows—

	Right.	Left.
Ulna—Styloid process to olecranon	24 cm.	25.5 cm.
Radius—Styloid process to epicondyle	26 cm.	28 cm.
Circumference of forearm 5 cm. below olecranon	22 cm.	24.5 cm.

There is a shortening of the ulna of 1.5 cm. and an apparent shortening of the radius of 2 cm. The atrophy of the forearm is 2.5 cm.

Radiographic examination shows a fracture of the ulna at the junction of the upper with the middle third and a dislocation of the head of the radius forward and slightly outward. There is a moderate deformity of the fractured bone consisting in a bowing forward and outward, the lower fragment overriding the upper and lying internal to it. There is bony union with a fair amount of callus. (See Fig. 2 and 3.)

The diagnosis of the bone and joint lesion being evident, there still remained to be considered the exact nature and site of the nerve lesion, and what measures should be taken to increase the usefulness of the extremity. There was no doubt that there existed a musculo-spiral paralysis, and it was finally decided that this was due to a contusion or a laceration of the nerve, probably produced by the dislocated radial head. It was further concluded that the nerve was probably injured below its bifurcation into the posterior interosseous and radial as it was distinctly observed that the extensor carpi radialis longior, and especially the supinator longus, were not paralyzed. These muscles are supplied before the nerve divides.

The attempt at bloodless reduction of the old dislocation naturally failing, operation was decided upon with the following indications:

1st. To investigate and repair the nerve injury if possible.

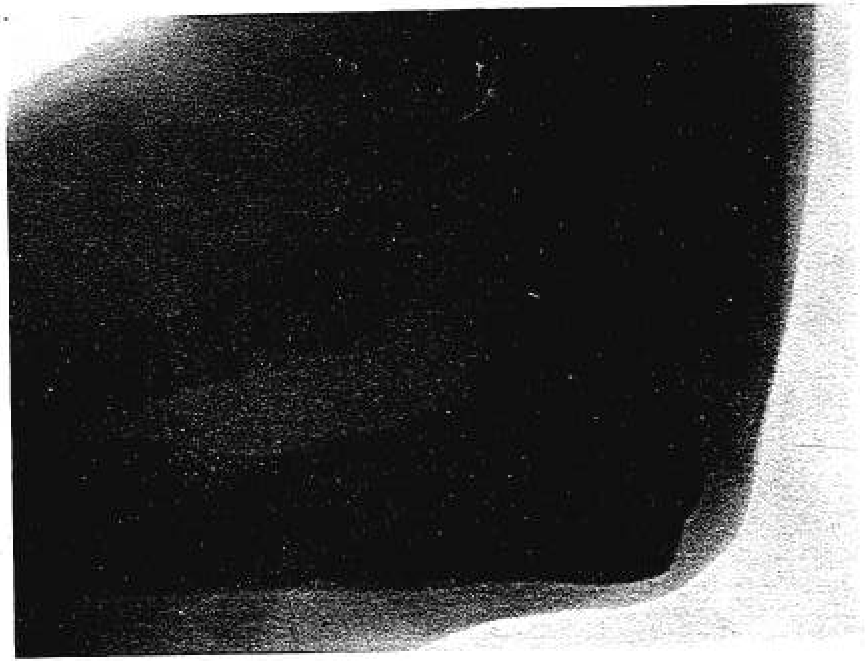
2nd. To increase the flexion of the elbow by either reducing the dislocation or resecting the radial head.

The *operation* was performed on November 19, 1903, by Dr. F. Kammerer.

A 10 cm. longitudinal incision was made directly over the prominent head of the radius. The supinator longus was exposed, and just medially was seen the protruding radial head which had pushed sharply inward the two divisions of the musculospiral nerve. (See Fig. 4.) The head of the bone is somewhat hypertrophied and the cartilaginous surfaces are no longer glossy. Both branches of the nerve are much flattened, and the nerve fibres are apparently ruptured. It seems as if the ends are held together by thin, flat, fibrous strands, the remnants of the nerve sheaths. This is particularly true of the radial branch. After carefully freeing the nerves and pulling them aside, the head of the radius was resected with the Gigli saw and the nerves allowed to return to their normal position. (See Fig. 5.) The wound was closed without drainage, the arm was put in semi-flexion, midway between pronation and supination. The patient made an uneventful post-operative recovery. The wound healed primarily. After a month, the plaster dressing which had been applied was removed, and then under massage, passive motion, and electrical treatment the flexion of the elbow and the nerve function were gradually improved. When the patient left the hospital on January 22, 1904, the anaesthesia had greatly diminished, and there was a marked increase in the extension of the fingers and wrist and in the flexion of the elbow. The electrical reactions still showed degenerative changes, but also evidences of marked improvement. Galvanism and faradism to the nerve trunk gave sluggish contractions, as did faradism to the extensor communis. The galvanic response of the muscle was prompt and the A. C. C.>K. C. C. was still present.

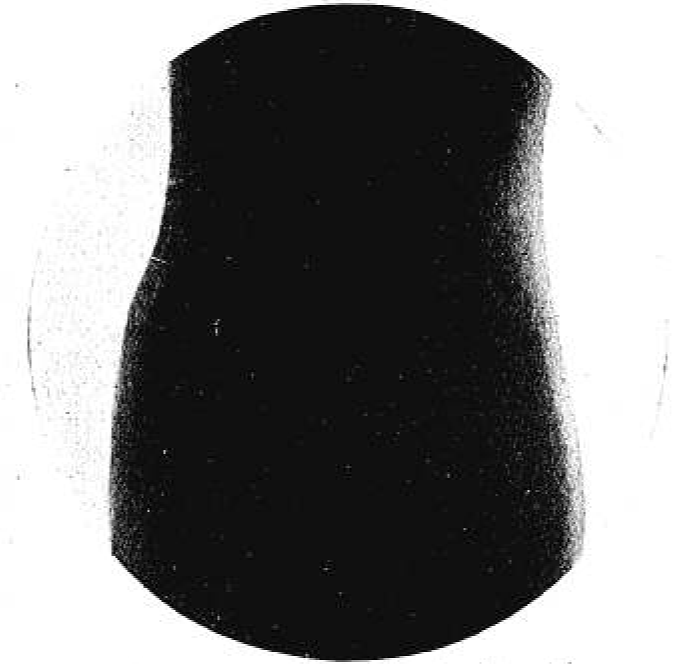
The condition of the patient continued to improve, so that at the end of the three years he was practically well. He was last seen by the writer January 18, 1908. He states that for the past

FIG. 6.



Skiagram four years after operation. Flexion. Lateral.

FIG. 7.



Skiagram four years after operation. Extension. Anteroposterior.

year the condition has been stationary and that aside from an occasional trembling of the thumb, a grating at times in the joint on turning forearm, a very slight muscular weakness of the hand, and an insignificant numbness of its back and outer side of the ball of the thumb, there are no subjective symptoms. The patient is easily able to follow his present trade of tinsmith.

EXAMINATION.—*Inspection* shows nothing but a healed linear scar in the bend of the elbow. There are no trophic changes.

Palpation.—The upper extremity of the radius gives the impression of being the normal head in proper position, rotating under the examining finger. The bowing of the ulna can be felt, but is not striking.

Motion.—Flexion at the elbow is almost perfect. Extension is slightly more than normal. Supination and pronation are unimpaired, though passive motion reveals an occasional crepitation in the superior radial joint. There is a very trifling limitation of extension at the wrist and all the movements of the fingers are perfect. The grip is strong.

Sensation.—There is slightly impaired sensation of the hand corresponding to the previous area of total anaesthesia. This is most marked on the back of the hand between the first and second metacarpals.

Electrical reactions of the nerve trunk are normal. Local stimulation of the extensor communis with the faradic current gives a somewhat sluggish response. The muscle does not appear hyperexcitable to galvanism, but A. C. C. = K. C. C.

Mensuration.—There have been no changes in the bony measurements, but the circumferences of both forearms, 5 cm. below olecranon are equal, 26 cm.

Radiographic examination shows the upper extremity of the radius rounded and slightly hypertrophied. It is not in contact with either ulna or humerus and seems to lie free in the soft parts. The fracture shows very good union. The angle resulting from the displacement has been filled in by new bone. Superiorly and laterally there is at the site of fracture an apparent hyperostosis, irregularly shaped and of moderate size. (See Figs. 6 and 7.)

Interest in the above case, and the very successful outcome of the surgical treatment, induced the writer to examine the literature of ulnar fracture combined with dislocation of the head of the radius, particularly in reference to the mechanism, the unity, and the types of the injury, on the one hand, and to the nerve complication, on the other. This in turn led to a series of cadaver experiments which were made with the double purpose of reaching some definite conclusion concerning the former problem, in regard to which, since Malgaine's original contribution in 1854, there existed a mass of doubt and contradiction, and of studying the anatomical relations of the dislocated radial head to the musculo-spiral nerve, and the frequency with which the nerve is involved. I shall not discuss here the question of the combined bone and joint injury, for I propose publishing the results of my researches in this matter at some future date, but shall devote my entire attention now to the latter subject.

Before discussing that particular point which is of especial interest to us here, namely, musculo-spiral nerve injury as a complication of dislocations of the upper extremity of the radius associated with ulnar fracture, it is important that the following be understood: Those deductions drawn in regard to the typical injury of the nerve in cases of the characteristic combined bone and joint lesion, apply in a certain measure to isolated dislocations of the head of the radius. The difference is simply that the latter class of cases is rarer than the former and hence the neurological complication is seen more frequently with ulnar fracture. Another factor that explains the relatively greater frequency of nerve involvement in the fracture cases, is that a greater dislocation of the head of the radius is possible when the ulna is broken than when it is intact, and hence the musculo-spiral nerve or its branches are more likely to be damaged. I have purposely not considered in my discussion injury to the nerve in dislocations of both bones of the elbow. Here the traumatism to the soft parts is so extensive and diffuse, that to draw a characteristic pathologic-anatomical picture of the lesion were well nigh out of the question, though it is not unlikely that musculo-spiral injury even in these instances could occasionally be grouped with the typical cases.

RESUME OF THE LITERATURE.

The first distinct reference to the nerve complication is made by GRENIER[1] in 1878. In his thesis on fracture of the ulna, combined with dislocation of the radius, he casually notes in reporting one of his cases that the patient suffered from an extensor paralysis which yielded to electrical treatment. The forward dislocation was never reduced.

The second case is DOERFLER'S[2] (1886) of complete and permanent paralysis of the extensors in an old unreduced outward and slightly backward dislocation of the radius, with compound fracture of the ulna. He gives an utterly hopeless prognosis in cases of nerve injury.

The third report is by WINNET[3] (1894) of a four weeks' old forward and outward dislocation, with fracture of the ulna and a posterior interosseous paralysis. There are no data given as to the outcome of the nerve injury.

The fourth time that this lesion is recorded is by ANNEQUIN[4] (1898). He gives a detailed account of a case of a month-old forward and slightly outward dislocation with ulna fracture, in which the motor power of the hand was diminished, several anaesthetic zones existed on the hand and forearm, the hand was moist and cold, and the nails showed trophic disturbances. Extension of the elbow caused painful radiations along the radial branch. This is the first case in which both motor and sensory branches were involved, and both incompletely. Resection of the head of the radius brought about a complete restoration of function.

ALBERTIN[5] (1898) gives us the fifth clinical report of this injury. The patient sustained a fracture of the ulna at its middle, with a forward dislocation of the radius. A musculo-spiral palsy developed at once. The radial head was resected and the paralysis gradually disappeared.

The sixth record is SCHAEFER'S[6] (1899). In this case, due to a forward dislocation of the radius complicating an ulnar fracture, there developed an immediate complete anaesthesia of the hand with total flexor and extensor paralysis. An injury to the median, ulnar and musculo-spiral nerves was assumed, and operation fifteen weeks after the injury, consisting in freeing the nerves from their bed of scar tissue, resulted in a complete recovery seven months later.

The seventh observation is made by WILMS[7] (1903), who incidentally remarks that the musculo-spiral nerve was paralyzed in a case of forward and outward dislocation, with fracture near the middle. The case comes from the Trendelenburg clinic and a skiagram is reproduced. No details are given.

The eighth and last reported case is one of Le Dentu's, quoted by MARSAN[8] (1906). The patient sustained a fracture of both bones of the forearm and a forward dislocation of the head of the radius. A variety of trophic disturbances ensued. No distinct reference is made to the exact nerve lesions except that it is noted that there was a zone of anaesthesia in the area of the distribution of the radial, presumably due to pressure on the anterior branch of the musculo-spiral by the head of the radius. The cold, violet red hand, the "main-en-griffe," and the anaesthesia were present at the end of three years and were apparently permanent. The head of the radius was not resected.

The case that the writer has observed is then the ninth recorded case of nerve injury in dislocation of the head of the radius complicating fracture of the ulna. He might state here that the total number of cases of the combined bone and joint injury found in the literature was one hundred and nineteen. He has found but one case of nerve injury in isolated dislocation of the head of the radius.

This is reported by CARREY[9] (1894), who states that his patient had an old forward dislocation of the head of the radius and shortly after the injury developed a musculo-spiral paralysis. There was anaesthesia, mainly on the radial side of the hand, extensor paralysis of the wrist and fingers, with marked atrophy and hyperidrosis. The head was resected on account of limitation of motion in the elbow, and fifteen months later there was a good functional result, though no direct reference is made to the restoration of nerve function.

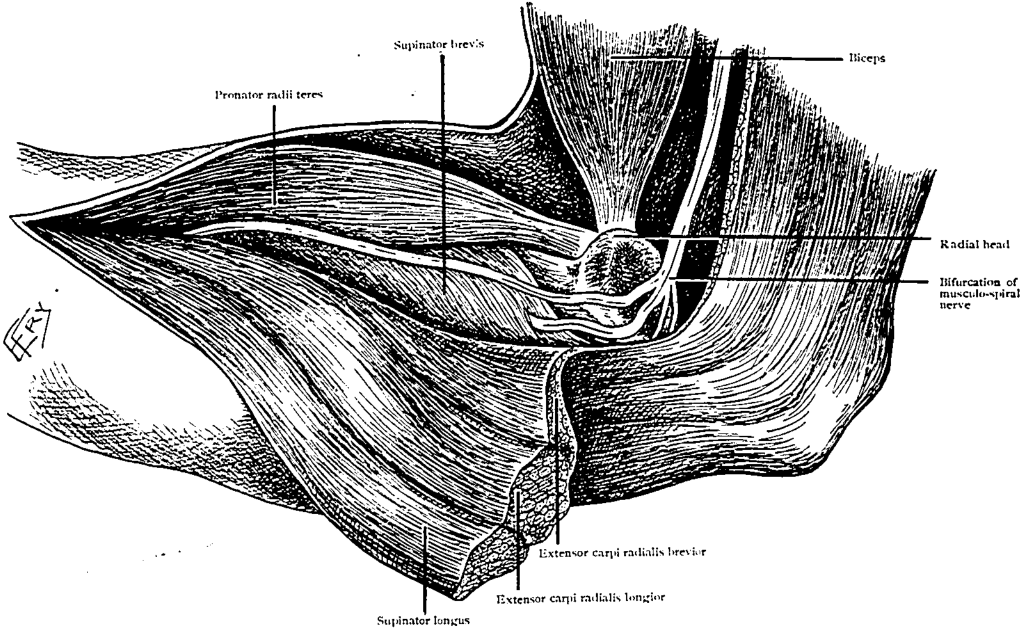
Aside from these clinical records a number of definite anatomical observations have been made, showing that the musculo-spiral nerve is in very close relation to the dislocated radial head.

SCHUELLER,[10] in 1885, first pointed out that the nerve can be stretched just at its point of division by a forward dislocation, and that the deep branch might be involved in other varieties. He demonstrated this by a cadaver experiment and published a picture of the nerve caught by the dislocated head. (See Fig. 8.) The clinical aspect is not considered.

LOEBKER,[11] the next year, substantiated this fact by a number of experiments and also represented the condition graphically. His picture shows the two divisions of the nerve around the neck of the forward dislocated radius. (See Fig. 9). He urges care in operative work on the radial head, advising a lateral incision to avoid the nerve. He admits having almost divided the nerve in one attempt to resect the head and further states that he knows of a case in which a careless operator directly severed the nerve in attempting resection. His remarks refer purely to the surgical anatomy of the situation and he entirely disregards the possible clinical picture.

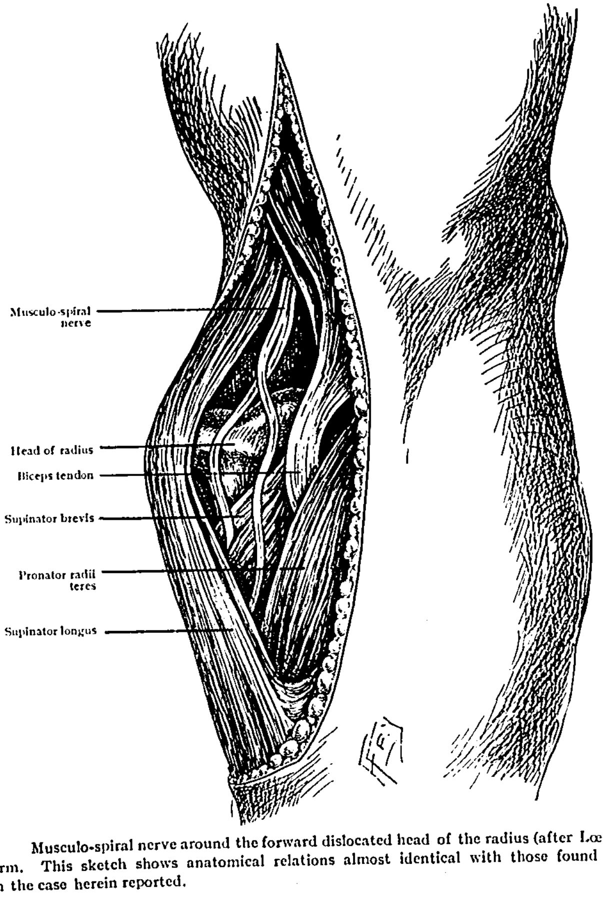
DOERFLER also calls attention to the relations of the nerve to the dislocated head, as he noted them in two of his cadaver experiments. In one forward dislocation the nerve was around the neck of the radius and in another instance of forward and outward dislocation it was stretched over the head just at the point of division. In both cases exaggeration of the dislocation—hypertension—would have torn the nerve.

FIG 8.


Supinator brevis
Pronator radii teres
Biceps
Radial head
Bifurcation of musculo-spiral nerve
FRY
Extensor carpi radialis brevior
Extensor carpi radialis longior
Supinator longus

Relation of the musculo-spiral nerve to the forward dislocated radial head (after Schueller). Left arm.

Fig. 9



Musculo-spiral nerve around the forward dislocated head of the radius (after Lœbker). Right arm. This sketch shows anatomical relations almost identical with those found at operation in the case herein reported.

Annequin noted in his case that the radial head had lifted up the musculo-spiral nerve and **Albertin** made a similar observation at the operation on his patient. **Schaefer** also saw this condition though he did not resect, but simply loosened the nerve from the surrounding fibrous tissue.

In spite of these very positive anatomical observations and the fair number of reported cases, musculo-spiral involvement in radial head dislocation with or without fracture of the ulna has been very generally ignored by the medical teachers.

The older general surgeries make no reference to the subject whatsoever. Rieffel in Le Dentu and Delbet's "Traité de chirurgie" (1896) calls attention to Grenier's case, and Wilms in the 1907 edition of the "Handbuch der praktischen Chirurgie" mentions the lesion in connection with his case quoted above. The latter, however, in his chapter on injuries of the nerves at the elbow and in the forearm totally disregards the question, though he does speak of fracture of the radial head as a cause of the nerve injury. Tillmanns (1898) simply notes the possibility of the nerves being injured in complicated elbow dislocations, while Koenig (1900), though he devotes a separate chapter to injury of the soft parts at the elbow, does not so much as mention the typical lesion. Neither of the two most recent American systems on general surgery (1907) Keen's, and Bryant and Buck's make the slightest reference to musculo-spiral paralysis in elbow dislocations.

Bardenheuer, in his "Verletzungen der oberen Extremitaeten" (1888), remarks that the deep branch may be compressed in forward dislocations of the capitulum radii, and in his "Allgemeine Lehre von den Frakturen und Luxationen" (1907), he merely casually repeats this statement.

Of the special text-books on fractures and dislocations that I have consulted, the older ones, Hamilton (1891) included, contain no allusion to the nerve injury. Stimson (1907), in his chapter on fracture of the ulna with dislocation of the radius, mentions Doerfler's case and notes the possibility of the complication, but under the special heading of nerve injury due to dislocations, he absolutely overlooks the question. Helferich, in his "Frakturen and Luxationen" (1906), speaks of musculo-spiral paralysis as a possible complication of anterior dislocations of the upper extremity of the radius, as do Hoffa in his "Lehrbuch" (1904) and Hennequin and Loewy in their "Fractures des os longs" (1904), though none appears to appreciate the fact that the injury is a typical one or to lay any stress upon it. The last two, even, in their latest publication, "Les luxations des grandes articulations" (1908) do not consider the nerve lesion sufficiently important to mention at all.

Stanciulescu, in his dissertation on dislocations of the radius complicating fracture of the ulna (1890), notes that several cases of rupture of the anterior branch of the musculo-spiral have been recorded as due to radial dislocation, and Pascal, in his inaugural thesis on isolated dislocations of the head of the radius (1907), merely refers to musculo-spiral paralysis in passing. Zieger in his monograph on traumatic dislocations of the radial head (1901) makes a very casual reference to the possible nerve complication.

The text-books and systems on general medicine completely disregard the lesion, and the neurological works treat the subject in about the same manner. Gowers (1895), Dana (1904), Church and Peterson (1905), Oppenheim (1905), and Starr (1907) absolutely ignore radial dislocation as a possible cause of musculo-spiral paralysis, though every other conceivable etiological factor is noted. Grasset and Rauzier (1894) do speak of elbow dislocation as a cause of nerve lesion, but do not specify.

In their monographs on injury of nerves, Weir Mitchell (1872) and Bowlby (1889) both devote a special chapter to injuries due to dislocations, but our particular type is totally neglected. Pearce Bailey's volume of "Diseases of the Nervous System Resulting from Accident and Injury" (1906), likewise contains no allusion to it. Schede and Graff in their article on the surgery of the peripheral nerves in Penzoldt and Stintzing's "Handbuch" (1903) totally disregard dislocation of the radius in the etiology of musculo-spiral palsy. Bernhardt, in his "Erkrankungen der peripherischen Nerven" (1902), remarks that fracture of the head of the radius can cause nerve injury, but no word on dislocation. He is no more explicit in the volume on nervous diseases of the "Deutsche Klinik" (1906). Chapoy (1874), Biberfeld (1893), and Potain (1896), writing on the special subject of musculo-spiral paralysis, are apparently unaware of the danger of traumatism to the nerve from the dislocated head.

Summarizing the situation it is seen that, while a moderate number of cases have been put on record and several investigators have noted distinctly the anatomical connection between the musculo-spiral nerve and the dislocated head of the radius, the fact that this nerve lesion is a typical and characteristic one, has been entirely overlooked. In fact, the very possibility of the injury is only admitted by an occasional author on general surgery, and perhaps somewhat more frequently by those dealing more specifically with dislocations, though in neither instance is any importance attached to the matter nor its significance appreciated. Absolutely no reference is found to this type of nerve injury among the general medical and neurological writers, be it among those dealing with nervous diseases in general, with nerve injuries in particular, or even with musculo-spiral paralysis exclusively.

Of course, the general disregard of this subject by the medical writers is explainable by the rarity, first of radial dislocation, and secondarily of the nerve complication, but the significance and importance of the latter and its comparative frequency in cases of the joint injury have justified the writer in performing the following cadaver experiments to determine the relations of the nerve to the dislocated head and the regularity of the involvement. As he was also interested in the mechanism of the combination of radial dislocation with ulnar fracture he always produced this type of injury. Further, this is the easiest way of causing a dislocation of the radial head, and finally this was the type of radial dislocation which represented the vast majority of the clinical observations quoted above and thus the conditions during life were most closely imitated.

EXPERIMENTS.*

EXPERIMENT I.—January 6, 1908. German Hospital. Left arm of medium-sized, middle-aged, female body. Ulna partly sawed through at upper third and forearm bent back over edge of block. Fracture, with forward dislocation of head of radius.

Dissection.—After separating the fibres of the supinator longus, both branches of the musculo-spiral nerve, about 2.5 cm. below the bifurcation, are found twisted around the neck of the radius and pushed slightly outward by the head. On reduction of the head the nerve slips off, but on redislocating so that the dislocation is slightly more outward, the two branches are directly lifted up by the head. If the dislocation be exaggerated, the nerves are dangerously stretched and they could even be lacerated by continuing the hyperextension. Flexion of the elbow relaxes the tension on the nerves. A tight bandage, with the dislocation unreduced, would severely crush the nerve against the radial head. On reducing and redislocating further inward the nerves escape.

EXPERIMENT II.—Right arm of same body. Fracture and dislocation produced as above, but in such a manner that the dislocation is somewhat more outward.

Dissection.—Separating the fibres of the supinator longus one strikes the two divisions of the musculo-spiral a short distance below the bifurcation stretched over the radial head like violin strings over a bridge. Hyperextending the forearm would tear the nerves. Flexion relaxes them. Simple forward dislocation catches only the radial branch, while more direct outward displacement catches only the posterior interosseous.

EXPERIMENT III.—January 20, 1908. Cornell University. Left arm, exarticulated at shoulder of frail, elderly, female cadaver. Colles' fracture and fracture at middle of ulna produced by blow on palm and anterior dislocation of head of radius caused by simple hyperextension and supination.

Dissection.—Separating the supinator longus one sees the two branches of the musculo-spiral lying to the outer side of the head. The radial is in direct contact with the bone. There is a fracture of the radial head. If the dislocation be made a trifle more outward both branches are caught on the head and are stretched by exaggerating the dislocation. An attempt to rupture nerve by hyperextension is unsuccessful owing to the fact that the upper part of the nerve is not fixed. Even exposure of the trunk of the musculo-spiral in the upper arm and holding this, does not permit of rupturing. The nerve slips through the fingers. It is very tough and elastic, due probably to injecting fluids that have been used to preserve the body.

EXPERIMENT IV.—Right arm of same cadaver, also disarticulated from

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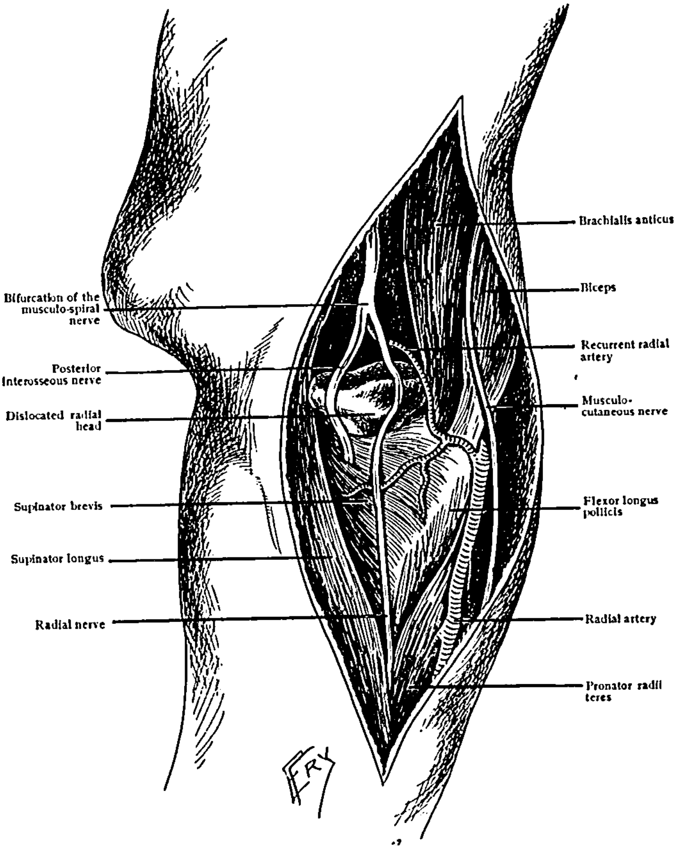
* Most of these experiments were performed at the anatomical laboratory of Cornell University through the courtesy of Dr. I. S. Haynes.

FIG. 10.



Sketch of condition found in Experiment IV. A similar state of affairs was found in Experiment II. This is a typical relation of the two divisions of the musculo-spiral nerve to the forward dislocated head of the radius.

shoulder. Compound fracture through base of olecranon, with forward and slightly outward dislocation of the head of the radius produced by blow of heavy mallet.

Dissection.—Shows the two branches of the nerve slightly stretched over the head of the radius as in Experiment II. The tension is increased by further extending the forearm and relaxed by flexion. (See Fig. 10).

EXPERIMENT V.—February 7, 1908. Cornell University. Right arm, fair-sized, elderly male cadaver. Fracture of ulna above styloid process and later at lower third. Hyperextension produced typical backward dislocation of both bones of the elbow, but incomplete.

Dissection.—Retracting the supinator longus, one sees both branches of the musculo-spiral relaxed and some distance away from the bone. This is particularly true of the radial, which could not possibly be injured in this dislocation. The posterior interosseous might be caught if the dislocation were more outward, but it is difficult to conceive how a simple backward dislocation could injure the nerve which simply relaxes and slips from the neck of the bone. In extreme dislocations backward it is possible that it might be stretched.

EXPERIMENT VI.—February 25, 1908. Cornell University. Left arm of cadaver used in previous experiment. Forward dislocation of the head of the radius, produced by hyperextension of the forearm after base of olecranon had been fractured by sharp blow of mallet.

Dissection.—The upper extremity of the radius has lifted up and stretched the radial nerve, while the posterior interosseous has entirely escaped. If the dislocation be reduced and the head of the radius be redislocated slightly more outward, both branches are caught. The nerve slips from the bone in an attempt to rupture by increasing the extent of the dislocation. If the radius after having been dislocated forwards, be pushed upwards about 2 cm., the main trunk of the musculo-spiral is impinged upon by the head of the bone.

Before drawing any further inferences from the above experiments, I shall now briefly discuss the

SURGICAL ANATOMY OF THE MUSCULO-SPIRAL NERVE AT THE ELBOW JOINT.

Piercing from behind forwards the lateral intermuscular septum above the lateral condyle, the musculo-spiral nerve quits its groove on the humerus, and descending between the brachialis anticus and supinator longus muscles it divides into two branches, the radial and posterior interosseous nerves, just above and in front of the eminentia capitata of the lateral condyle. Just above the point of division are given off muscular branches to the supinator longus, extensor carpi radialis longior and usually to the outer part of the brachialis anticus.

The radial nerve or superficial branch is slightly smaller, is situated medially, and is a purely sensory nerve. It passes over the humero-radial joint and then down along the radial side of the front of the forearm. It is covered by the supinator longus and is gradually approached on its medial side by the radial artery which meets it at about the middle of the forearm.

The posterior interosseous nerve or deep branch is the larger of the two divisions, lies external and posterior to the radial and is in the main a motor nerve. It passes over the humero-radial joint obliquely outward and downward, and just below the head of the radius it pierces the supinator brevis which presents a C-shaped opening for its reception. It passes between the two layers of this muscle, winds in a half spiral turn laterally around the upper part of the shaft of the radius and emerges posteriorly 6–8 cm. below the external epicondyle, lying between the extensor communis and the extensors of the thumb.

The point of division of the musculo-spiral and the two branches for several centimeters below it are then in direct relation to the humero-radial joint, only separated from the bone by the anterior and orbicular ligaments. The nerves are comparatively fixed in their position, and very slightly movable, hence liable to injury. The nerves are held in place in the fascia of the supinator longus, which, if lifted up, takes the nerves with it.

The superficial branch or radial supplies the integument of the radial side of the ball of the thumb, the greater part of the dorsum of the hand, the thumb, index, middle and radial half of the ring finger. It anastomoses with the musculo-cutaneous and ulnar nerves.

The deep branch or posterior interosseous supplies the following muscles,—extensor carpi radialis brevior, supinator brevis, extensor communis digitorum, extensor minimi digiti, extensores pollicis (longus et brevis), extensor indicis and extensor ossis metacarpi pollicis. A sensory terminal branch is distributed to the wrist joint.

CLINICAL SUMMARY.

Pathogenesis and Pathology.—In view of the anatomical conditions it is easily understood that in nearly every dislocation of the head of the radius the integrity of the two branches of the musculo-spiral is threatened. This is especially true of anterior dislocations. In this type, the upper extremity of the bone is likely to directly inpinge upon the two branches of the nerve, and this occurs almost invariably just below the bifurcation. As a result of the analysis of the reported cases and the experimental investigations I believe we are justified in assuming that:—

a. In forward and slightly outward dislocation one or both branches are most likely to be caught. Five out of nine of the cases with ulnar fracture demonstrated this.

b. In forward and inward dislocation, the nerves usually escape involvement.

c. In forward dislocation, the radial alone may be injured while the posterior interosseous may escape.

d. In outward dislocation the posterior interosseous alone may be involved and the radial may be free.

e. In backward dislocation, neither nerve is liable to be injured. It is almost out of the question that the sensory branch be affected in this type, but in extreme cases the deep branch might be stretched.

f. In forward dislocations where there is a marked displacement upwards the head of the bone might strike the main trunk of the nerve.

When the dislocation is a complication of fracture of the ulna, the nerve is much more likely to be affected, as the displacement of the radius is usually much greater under these conditions. While the literature of simple dislocation has not been reviewed by me as exhaustively as that of the combined fracture and dislocation, I have examined the large majority of the special papers on the former subject and have found but one case of nerve injury, while in the latter class I have found nine instances. Although there is great probability that even in simple dislocations the nerve injury is more frequent than the one case found would indicate, the proportion of one to nine is significant.

As to the exact nature of the nerve injury, this is usually a direct contusion by the protruding bone or an actual laceration, complete or partial, followed by the usual degenerative changes. In the operated cases, the nerves were never found completely torn across,—though in my case the nerve fibres seemed completely divided and the nerve ends were held together merely by fibrous strands, the remains of the sheaths.

The nerves are usually stretched directly over the radial head, and hyperextension, which exaggerates the dislocation, tends to increase the tension of the nerve, and likewise the injury. One or both nerves may be pushed medially or laterally, or the head may emerge between the two branches producing an injury in this position.

It is conceivable that under certain conditions the nerves might simply be stretched without coming in contact with the bones, and thus sustain, from the pull, a partial or complete rupture. This would be the mechanism in posterior interosseous paralysis due to posterior dislocations. The nerve injury usually takes place directly at the time of the joint lesion.

The frequency of this nerve complication is comparatively great as statistics of its incidence in cases of the double bone and joint lesion indicate. In the one hundred and nineteen cases of fracture of the ulna associated with dislocation of the upper extremity of the radius, which I have succeeded in collecting from the literature, the nerve was injured in nine cases, or 7.56 per cent.

Symptomatology and Diagnosis.—The symptoms are very much the same as the classical ones of musculo-spiral palsy added to the usual ones of fracture and dislocation or dislocation alone. They may be complete or incomplete in their distribution or their degree, depending upon whether one or both branches are involved and to what extent. As the main trunk of the nerve appears never to be injured, except in decided upward displacements, there may be only sensory or only motor symptoms, if only the radial or only the posterior interosseous be caught—or if both branches are damaged the symptoms will be mixed. Of the ten reported cases four were mixed, three were purely motor and one was apparently a purely sensory paralysis. In two the nature of the paralysis was not specified.

The usual anaesthesias in the area of the radial distribution, the extensor paralysis, and the trophic disturbances are too well known to detail here. These are regularly present and are partial or complete according to whether the nerve conduction be completely or only partially destroyed.

One characteristic and significant fact is that the supinator longus is not likely to be paralyzed, as its branch is given off just above the bifurcation.

The nerve symptoms usually develop promptly after the injury. The diagnosis of the lesion is self-evident.

Prognosis and Treatment.—The prognosis of this form of musculo-spiral paralysis is good, notwithstanding Doerfler's opinion to the contrary. In only two of the ten cases is it definitely stated that the paralysis was permanent. Six were positively cured, and in two the final result is not indicated. The ultimate restoration of function is of course best if the correct treatment be applied as soon after the injury as possible.

Treatment consists primarily in freeing the injured nerve and this, fortunately, generally corresponds to the regular treatment for the dislocation itself.

1. If possible, *i.e.*, if the injury is recent, a bloodless reduction might be attempted. This can be accomplished by extension, traction, and then flexion. Pressure on the head of the radius advocated by some authors should be avoided for fear of further damaging the nerve—as also hyperextension. After reduction, the arm can be put in plaster, in semi-flexion midway between pronation and supination. The ulnar frac-

ture simply requires the usual reduction of the deformity and anterior and posterior splints or a plaster dressing.

2. If the attempt at simple reduction is not successful and the ulna fragments are still ununited, an arthrotomy with reduction of the radial head and suture of the capsule tear, as advocated by Sprengel[12] in isolated dislocation, might be tried. However, this procedure will only be of service in very specially selected cases in which there has been no too great disturbance of the adjacent tissues. Further, if the articular surfaces have been destroyed, if the head is hypertrophied, and especially if the ulna fragments have united with shortening of the bone, arthrotomy is of little use.

Osteoclasis of the ulna, proposed by Doerfler, may be of service if the deformity of this bone is very great, but simply to lengthen the ulna in order to render arthrotomy possible, does not justify refracture.

3. Resection of the head of the radius, first suggested by Loebker[13] and later advocated by numerous other surgeons in old dislocations of the head of the radius, is unquestionably the operation of choice in the majority of older cases, where reduction is not possible by the bloodless method. This accomplishes the double purpose of relieving the nerve and of restoring the impaired elbow function in the simplest manner possible. The lateral incision of Hueter[14] should be used to avoid further damage to the nerve, and the most practical way of removing the head is with a Gigli saw. Four of the ten cases collected were cured by resection.

4. Suture of the nerve by one of the approved methods must of course be performed should it be found ruptured at the time of operation. Yet, if the remains of the nerve sheath hold the ends of the torn nerve together, it is scarcely necessary to sew the nerve, as my case demonstrates. If, after simple reduction there be no improvement within three months, the nerves must be exposed, as rupture or scars are probably responsible for the non-improvement and must be treated.

5. Electricity, massage, active and passive motion, and

stimulating medication should be used as adjuvants of the surgical treatment.

6. Prophylactically the following might be emphasized: In all cases of dislocation of the head of the radius in which the nerve is not involved, the fact that the nerve is in close relation to the dislocated head must be borne in mind and care must be exercised not to produce a nerve lesion by rough or careless manipulation, particularly in the sense of hyperextension or direct digital pressure on the head of the bone. The known proximity of the nerve to the radial head should in itself constitute a definite indication for reduction, for even if there is no primary paralysis a pressure paralysis may develop secondarily, if the dislocation remain unreduced. One should likewise avoid applying a tight bandage before the dislocation has been reduced, as the nerve might easily be compressed against the bone. Further, in all operations on the dislocated radial head the position of the nerve must be remembered, so that is is not injured by careless operative technique.

CONCLUSIONS.

1. Musculo-spiral paralysis as a result of dislocation of the head of the radius is a distinct type of nerve injury, and is quite as definite and characteristic as any other form of injury to this nerve. In fact, in every case of anterior dislocation of the head of the radius the two divisions of the musculospiral nerve are in danger and it is a fortunate accident if they escape.

2. Its actual occurrence is naturally rare, but comparatively, *i.e.*, compared to the frequency of the joint injury itself, it is not infrequent.

3. It is most likely to occur when the dislocation accompanies ulnar fracture and when the direction of the dislocation is forward and slightly outward.

4. The nerve is almost invariably injured below its point of division into the posterior interosseous and radial. One or both branches may be caught by the dislocated head.

5. The symptoms are practically those of the typical

musculo-spiral palsy. They may vary greatly in extent or degree, depending upon whether one or both nerves be injured and how badly. The supinator longus muscle escapes involvement.

6. The prognosis is good under appropriate treatment, which is practically the same as that for the dislocation: simple reduction, if possible, and generally resection of the head of the radius in old cases, with nerve suture if necessary.

7. Should the nerve be uninjured in a dislocation of the radial head, its close proximity to the bone should be borne in mind, the dislocation should be reduced, and care should be exercised not to injure the nerve, by pressure, hyperextension or careless operative technique.

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ADDENDA.

After this paper was finished, a publication by Sherren[1] appeared on injuries of nerves to which I refer here for the sake of completeness. He states that he has seen one case of musculo-spiral paralysis due to forward dislocation of the head of the radius and that Borchard has also observed the condition once. I have searched for the latter's report in vain. Sherren gives no particulars of the two cases, not even mentioning whether or not there existed a fracture of the ulna. He simply made the general statement that posterior interosseous paralysis, especially, may be a complication of dislocation and fracture of the upper extremity of the radius.

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[1] Sherren, J. Injuries of Nerves and Their Treatment, London, 1908, p. 233.